Science & Technology

In Pursuit of Dark Matter

Columbia physicists confront one of the most confounding mysteries in science.

By
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|
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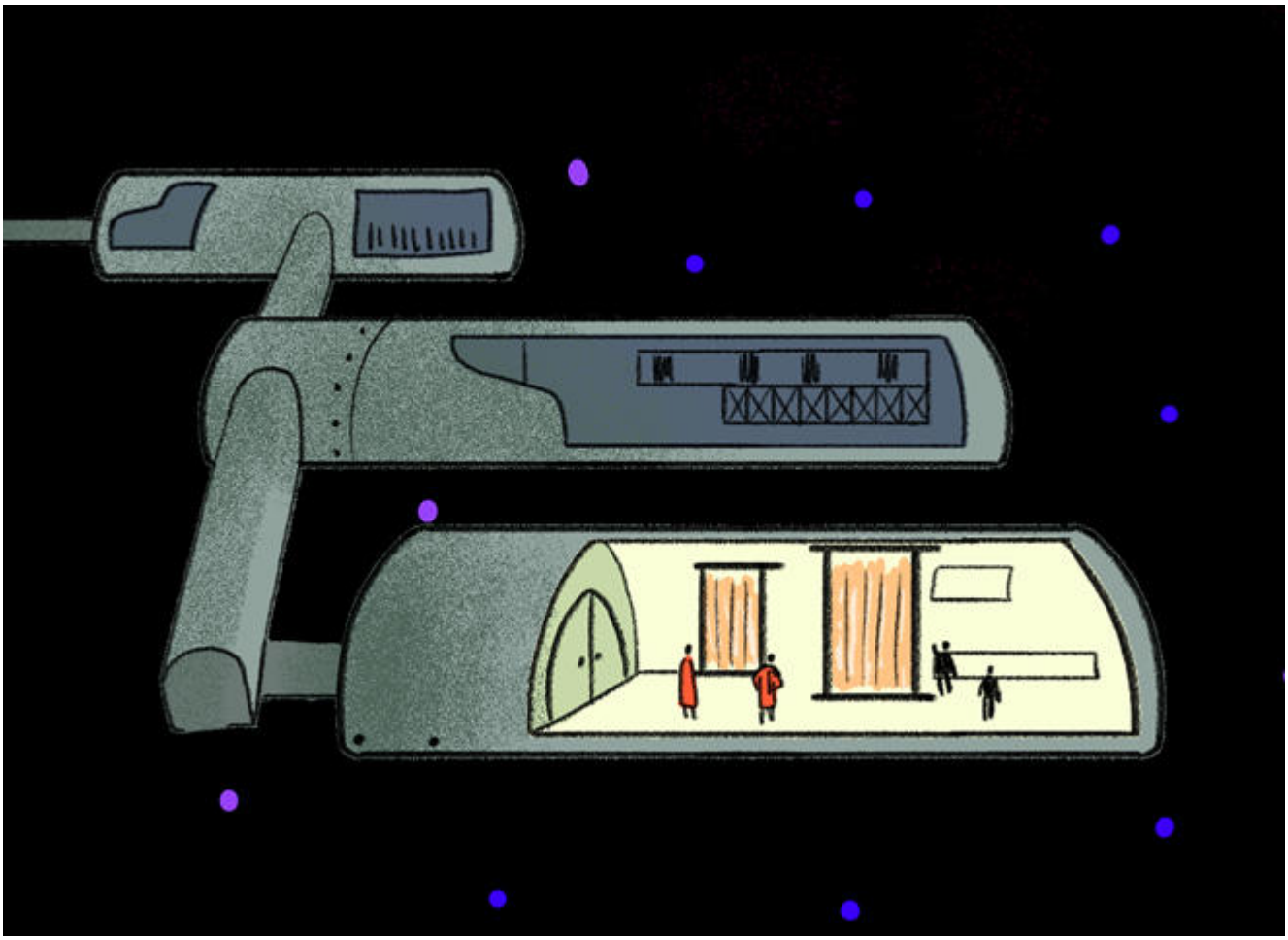
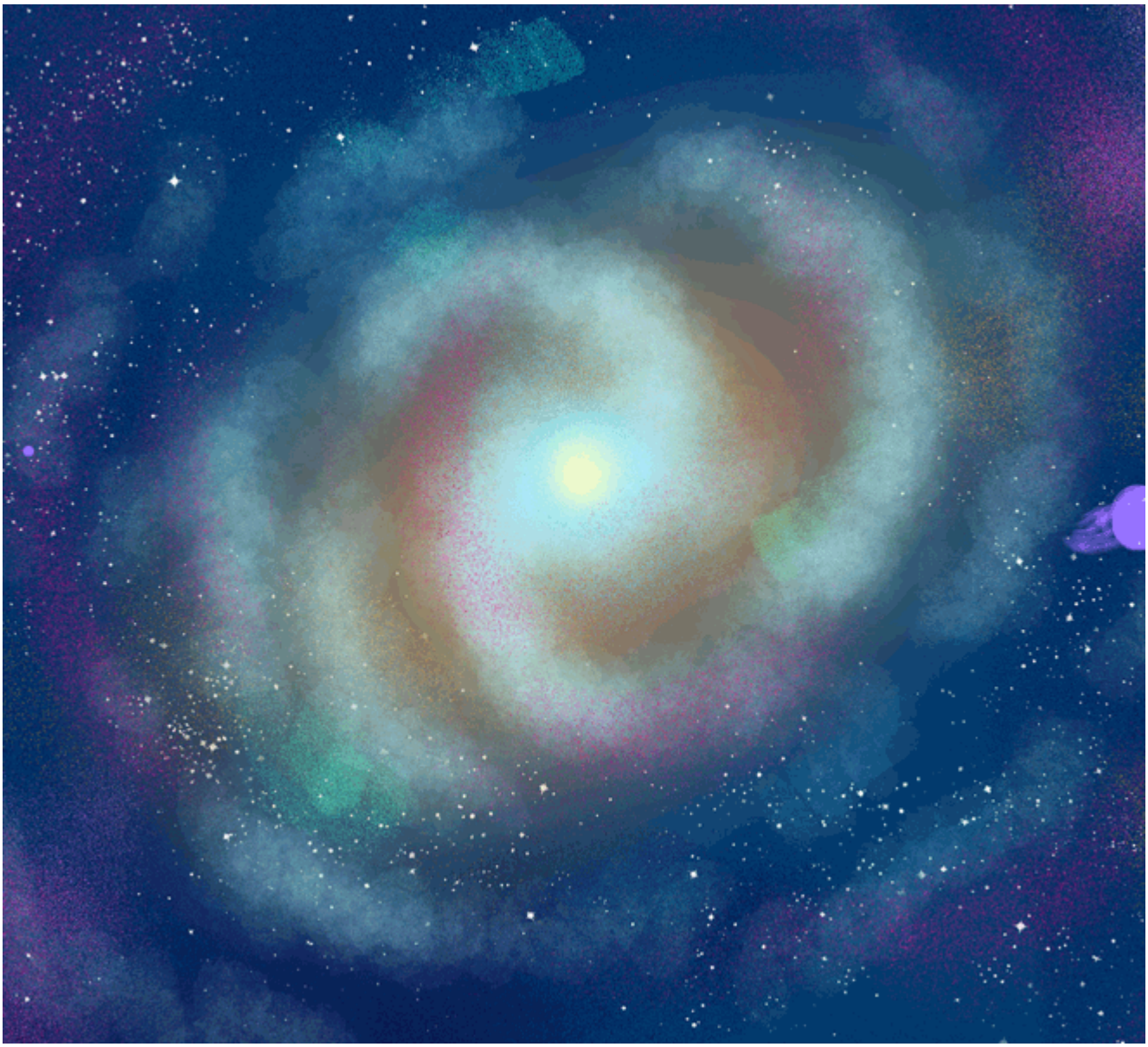
Deep beneath the Gran Sasso mountains in central Italy, the Xenon Collaboration, a global team of 170 scientists led by Columbia professor Elena Aprile, is searching for the most sought-after, controversial, and elusive substance ever described in a science textbook: dark matter.



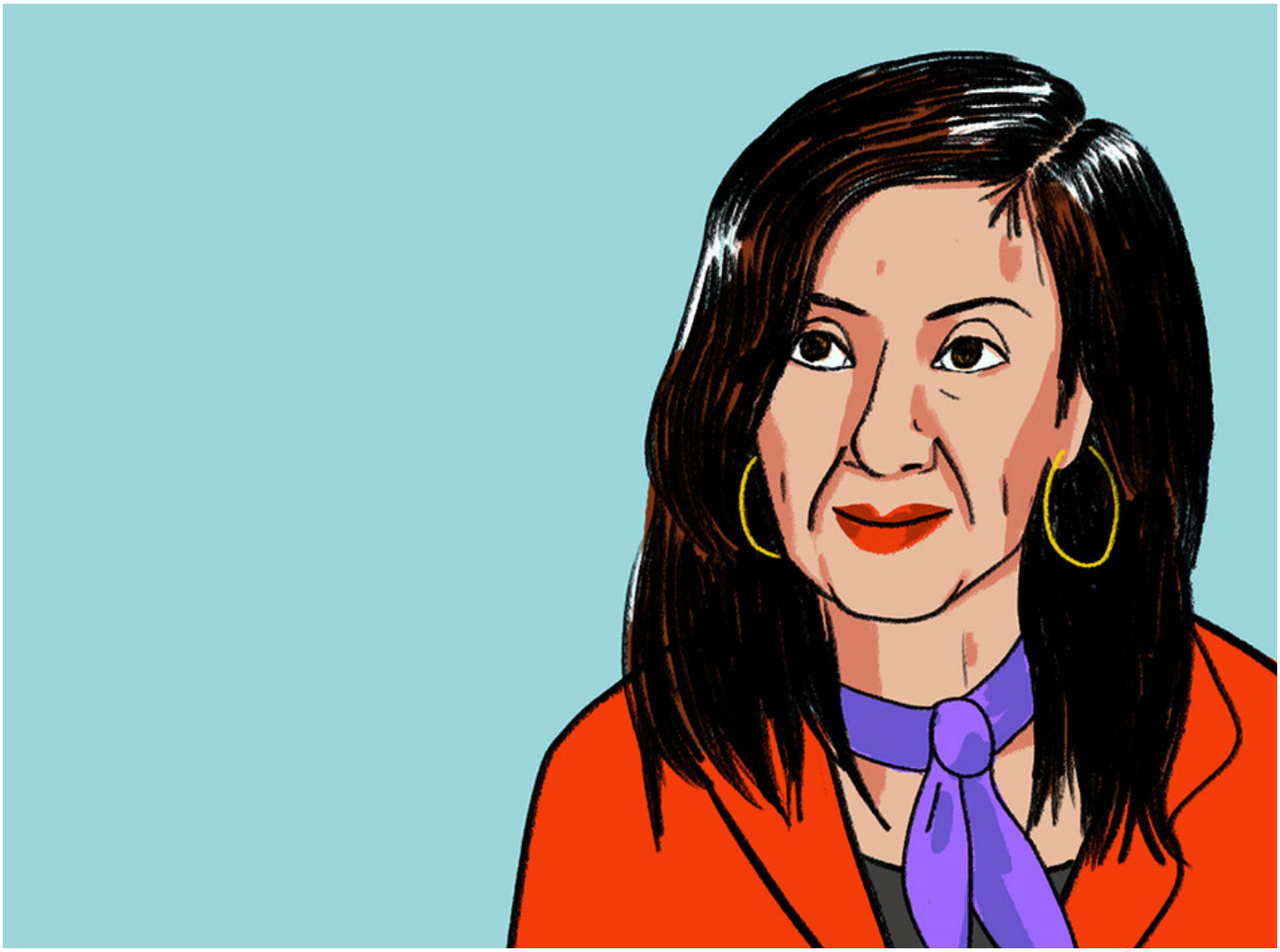
The stakes are high. Finding dark matter, a purely theoretical substance, would illuminate some of the deepest mysteries of time, space, and reality.

And if Aprile's team can't detect it soon, experts suspect, no one ever will.



The theory of dark matter holds that the world is permeated by mysterious heavy particles that drift harmlessly through ordinary substances. The idea was proposed decades ago to explain a number of curiosities that scientists have observed in the cosmos.

Consider the spinning motion of a galaxy... At its core, it contains too few stars, planets, and other masses to account for the gravity that keeps the celestial bodies on its perimeter from drifting off into space.



"If Einstein's theory of general relativity is correct, there is a huge discrepancy between the gravitational force we see at play in the cosmos and the total mass we're able to account for. By some estimates, we're missing 85 percent of all the physical stuff in the universe. 'Dark matter' is the name we've given to the material that seems to be missing."

— Elena Aprile

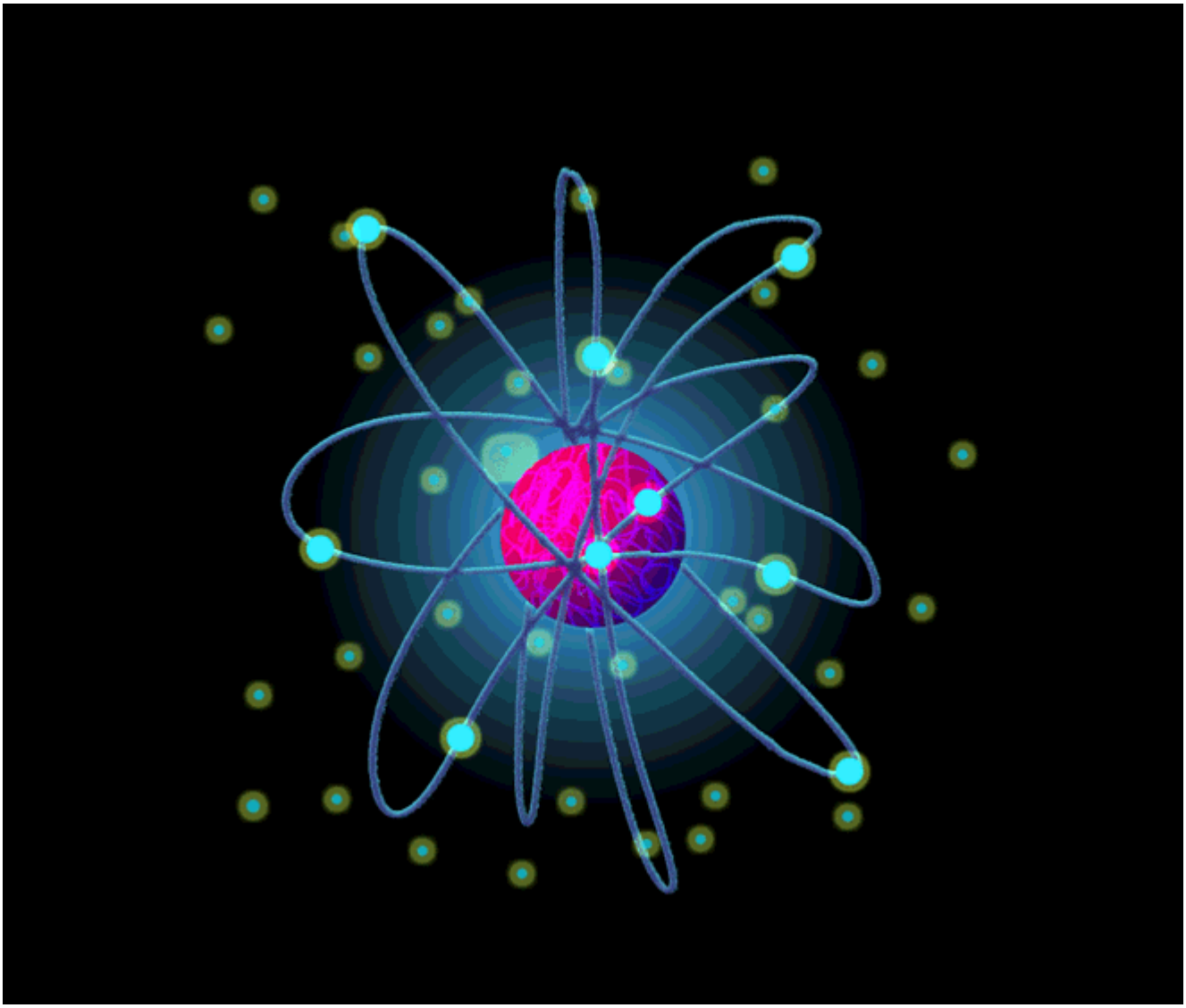


How do you hunt for something that is ubiquitous, yet invisible?

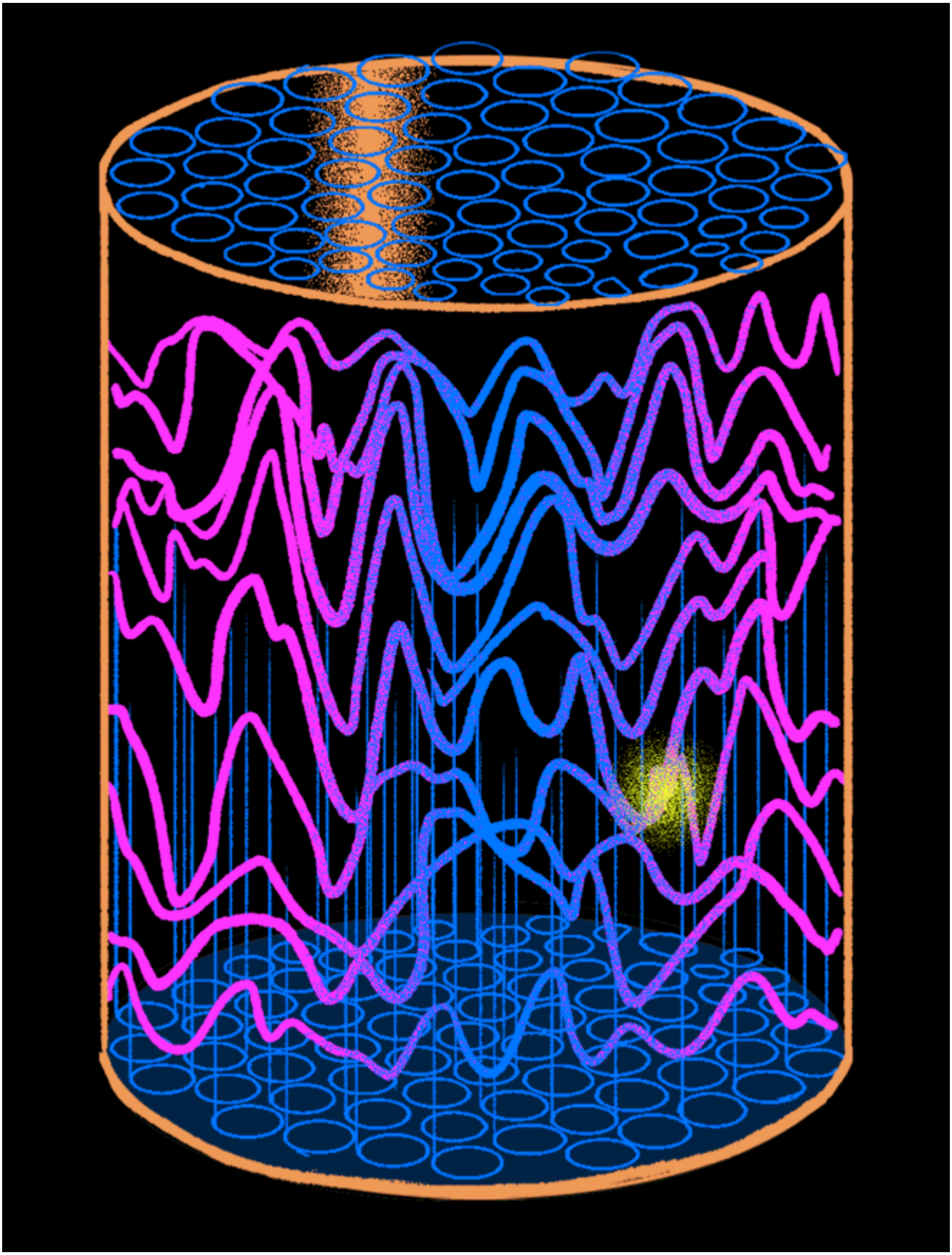
You set a trap that only it can enter.

Aprile's team works a mile underground to insulate their equipment from cosmic rays and other high-energy particles that continually pummel the earth.

In their laboratory is a stainless-steel drum filled with liquid xenon, which is three times denser than water. This syrupy liquid is their flypaper.

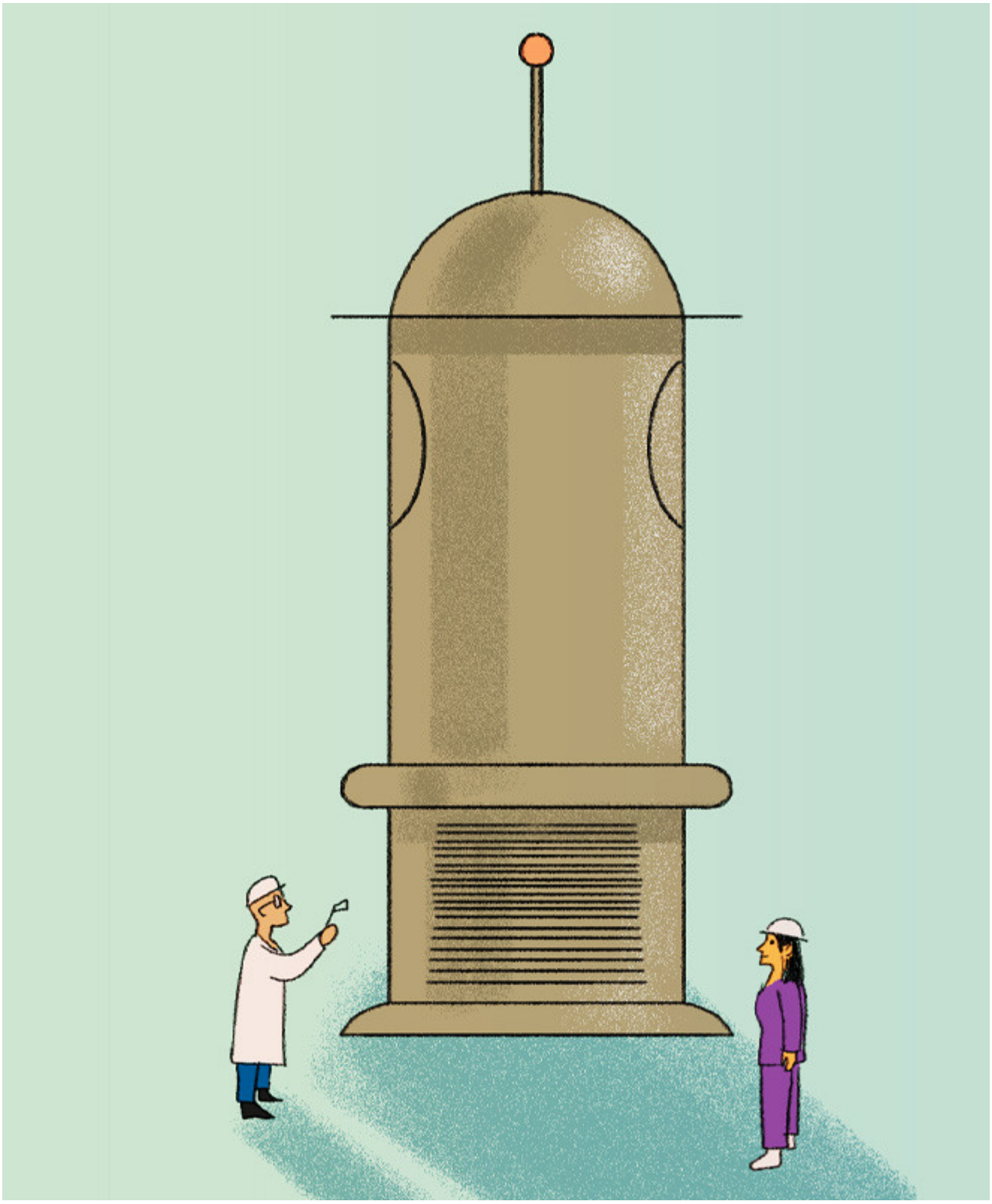


Particles of dark matter, despite their ghostliness, should occasionally bump into the atomic nuclei of a heavy element like xenon.

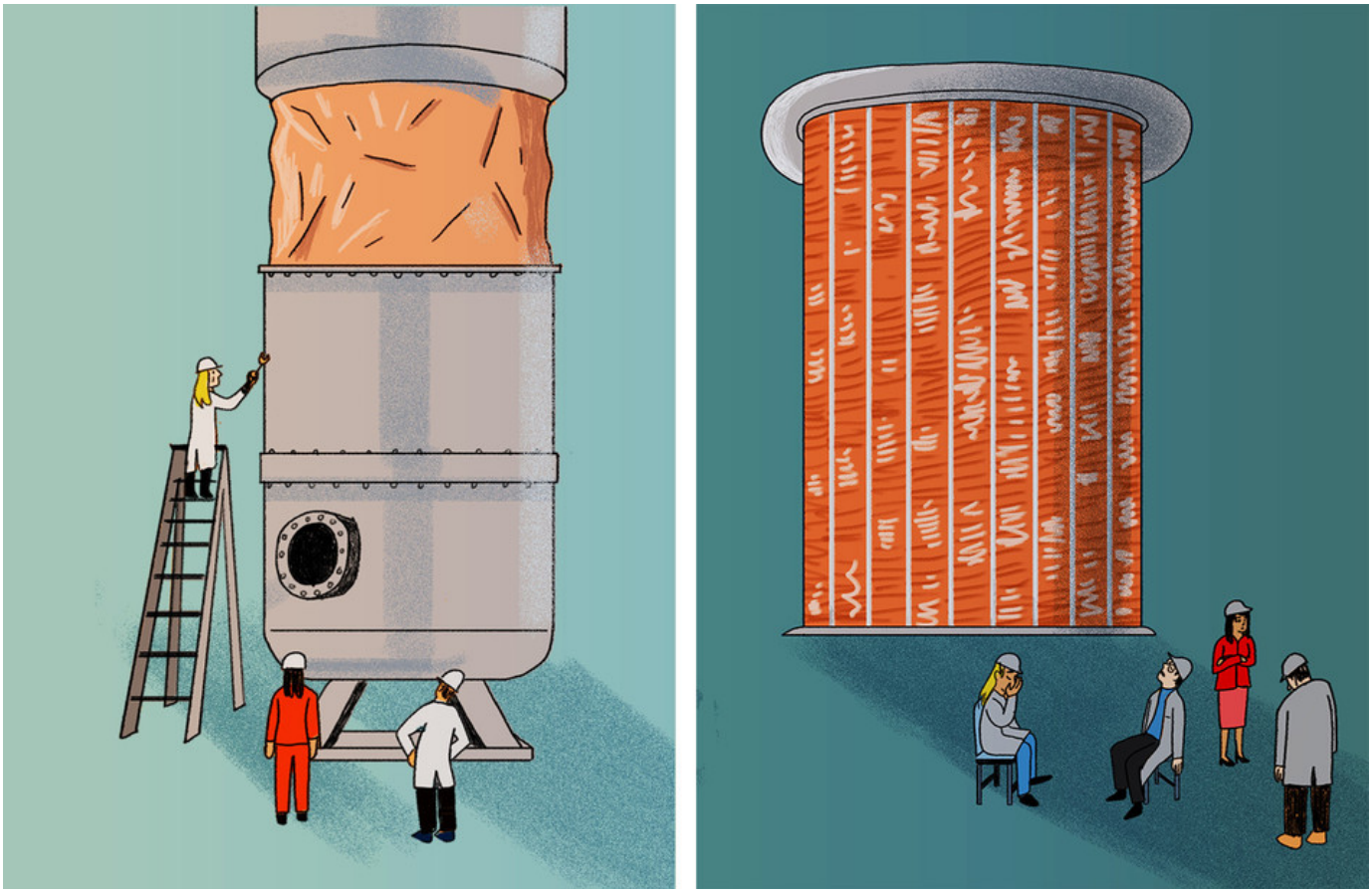


This would produce a minuscule flash of light — a pulse of energy so infinitesimal that 500 ultrasensitive photomultiplier tubes must be positioned atop and below the drum to detect it.

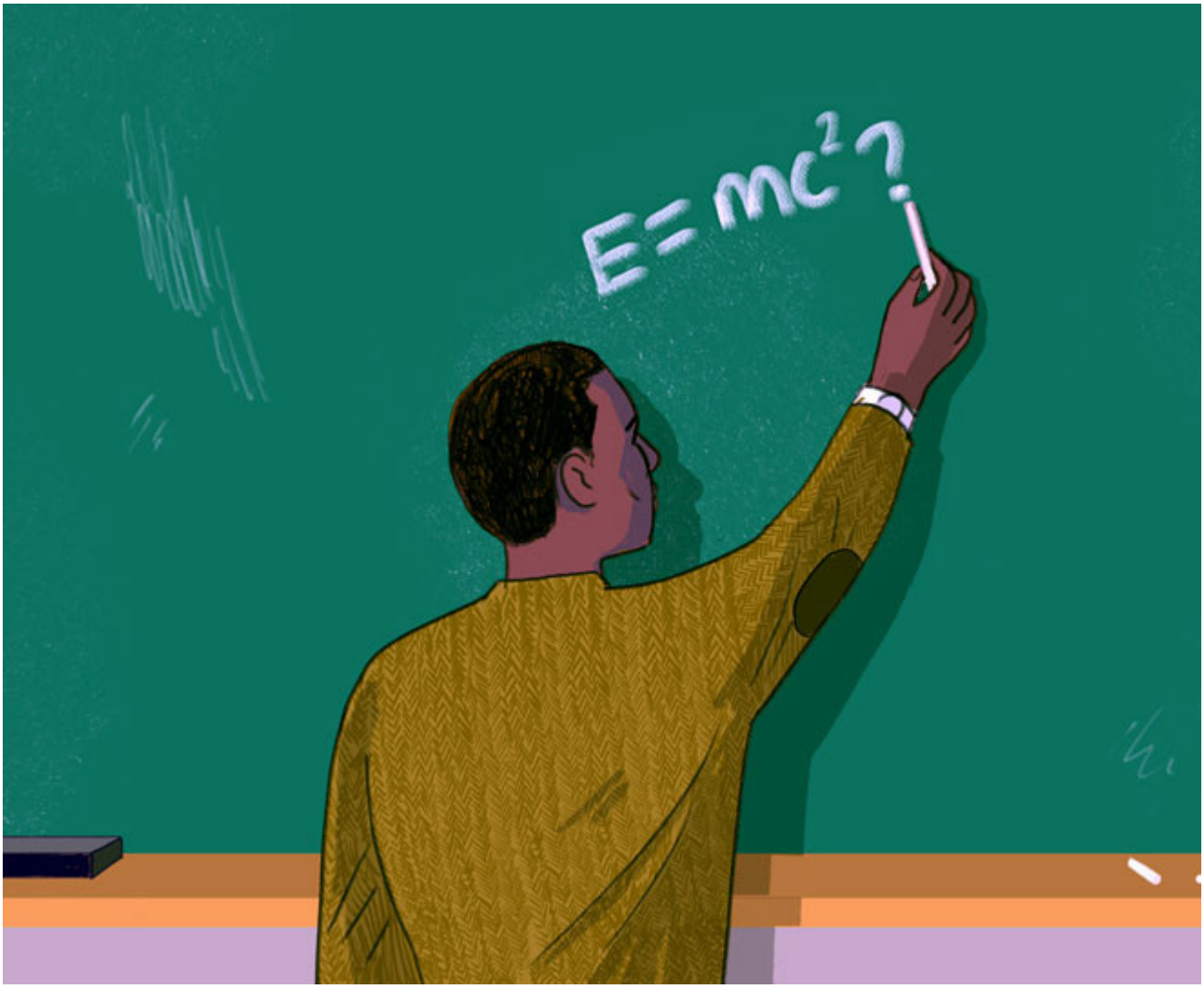
The scientists could scrutinize its signature for clues about their unseen guest's identity.



Since 2005, Aprile's team has designed, built, and operated a succession of increasingly powerful xenon-based particle detectors.



Time and time again, their experiments have turned up nothing.


E=mc²?

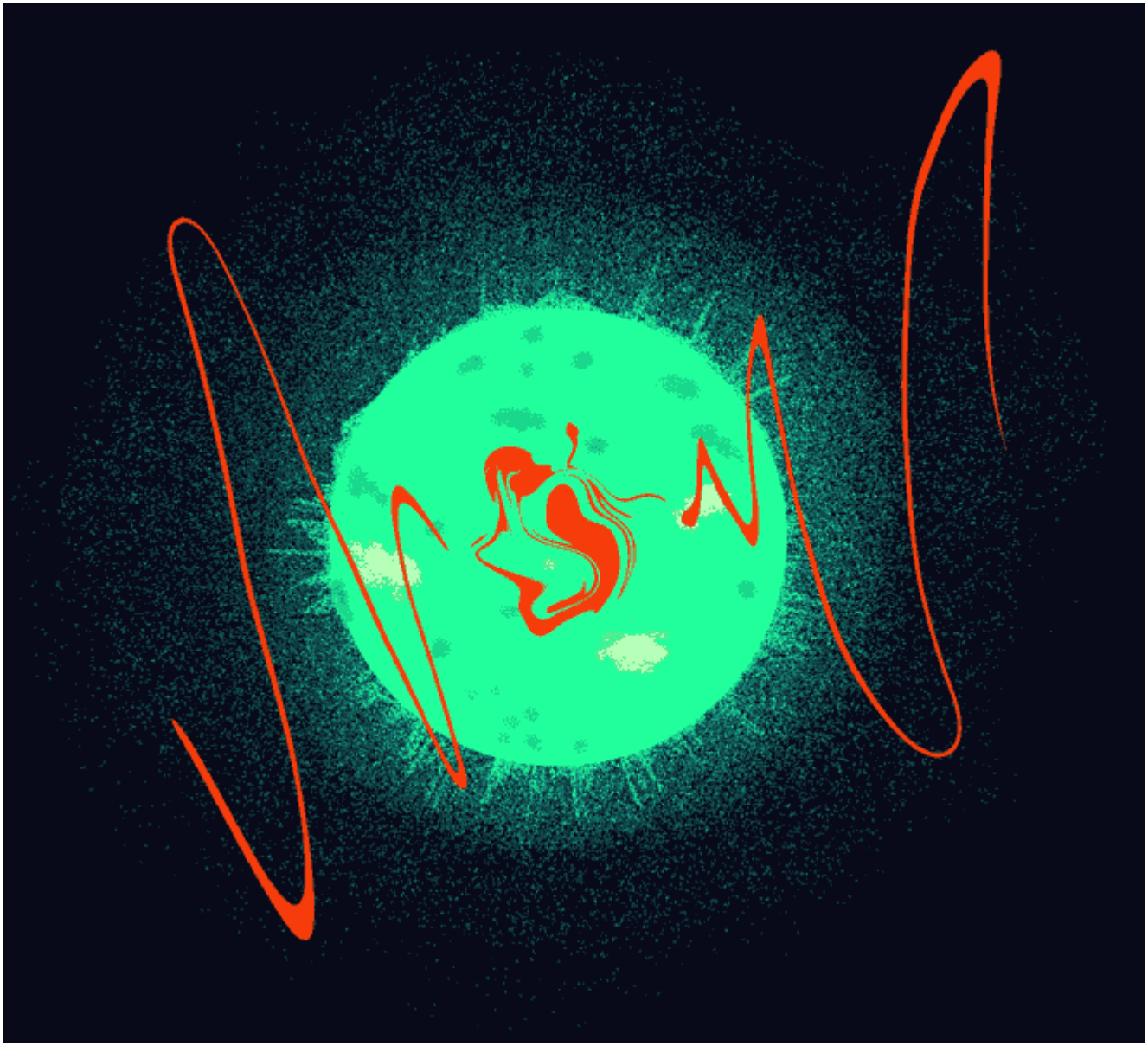
Which isn't to say their work hasn't been profoundly influential. As their detectors have become more sensitive, they have ruled out the existence of many types of dark matter that theorists had proposed.

In fact, the Xenon Collaboration has ruled out so many dark-matter particle candidates that theorists have gone back to the drawing board.

They wonder if maybe there isn't any missing mass in the universe at all! That maybe Einstein miscalculated how gravity works at large scales!

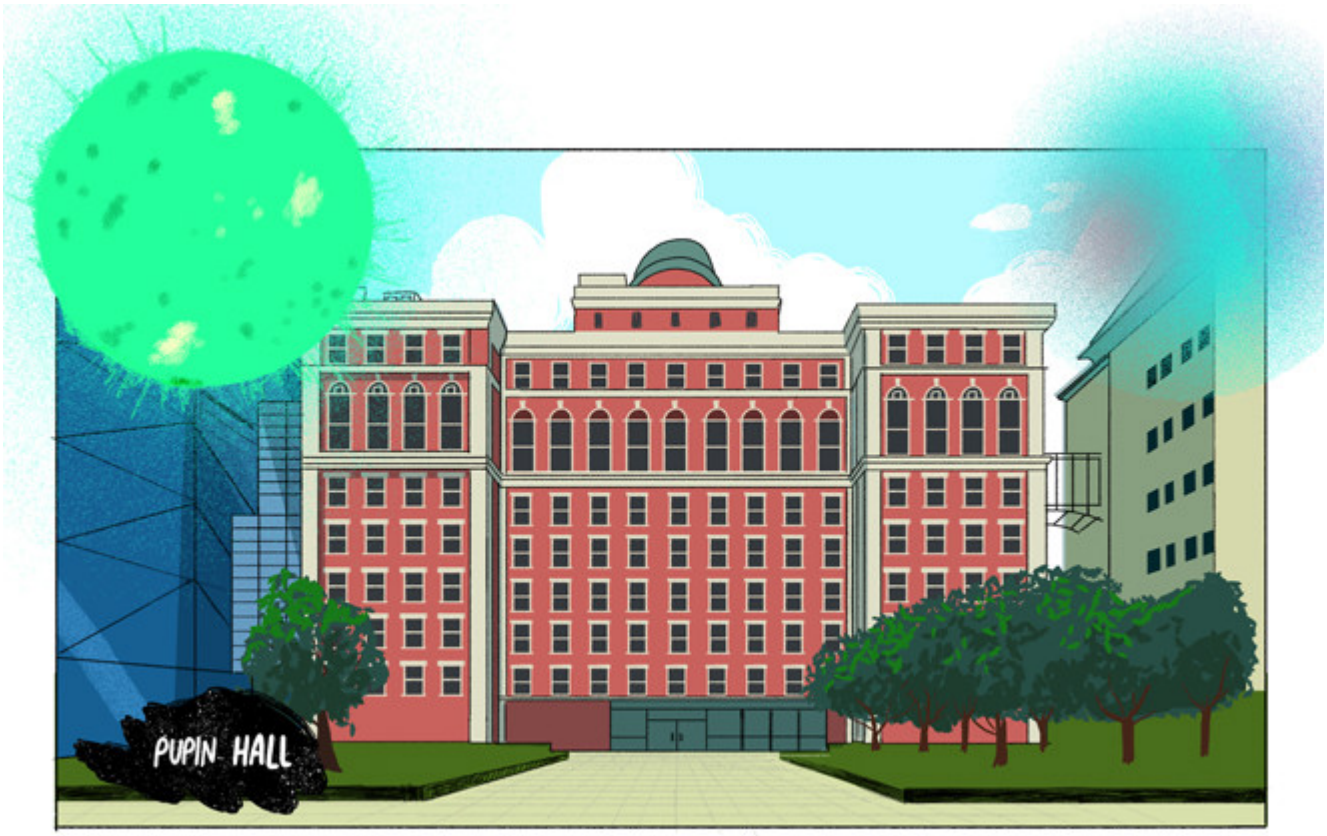


But in 2020 Aprile and her colleagues finally saw something! A series of flickers that might be evidence of a previously undetectable particle!



The scientists aren't sure yet what they saw. But among the likeliest possibilities Aprile believes, is a long-theorized, though never-before-seen particle called a "solar axion."

Finding a solar axion would rock the physics world. Although it is not thought to be a component of dark matter, it is closely related to another theorized particle that is. Spotting one would provide indirect evidence for dark matter's existence.



Today, a dozen young Columbia physicists in Aprile's lab are preparing to analyze data from a recently upgraded version of the detector. They hope to reveal the identity of their new particle — if it is a new particle — by the end of 2021. Will they find more bread crumbs on the path to dark matter? Or will they conclude that their recent finding was a mirage, thus casting further doubt on the theory of dark matter?



"When you're working at the outer limits of science, you never know what you're going to find. You may not find what you're looking for, or what you expect to see, and that's part of the adventure."
—Elena Aprile

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